Seasonal Occurrence of Night-Flying Insects on Barro Colorado Island, Panama Canal Zone

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This report summarizes the seasonal occurrence of night-flying insects attracted to ultraviolet-emitting fluorescent lamps ("black lights") on Barro Colorado Island. Observations were made between November 1967 and August 1968, during March 1970, and during June and July, 1971. Captures of insects in a malaise trap, operated between November 1967 and June 1968 are also tabulated for comparison.

Many ecologists who lack long-term experience in the tropics hold the common misconception that the tropics are relatively aseasonal, but numerous reports have demonstrated strong seasonal cycles in the occurrence of organisms or aspects of their behavior. For examples, readers are referred to Skutch (1950), Ricklefs (1966), Snow and Snow (1964), and Miller (1963) for reproductive cycles in neotropical birds, to Janzen (1967) and Smythe (1970) for seasonal patterns of flowering and fruiting in plants, to Wilson (1971) for the seasonal occurrence of reproduction in bats, and to Fairchild (1942), Galindo *et al.* (1956), Pipkin (1965), and Owen (1969), for seasonal cycles of abundance in particular groups of insects. For the most part, seasonal cycles in the tropics are closely tied to abrupt changes of rainfall associated with the onset of marked wet and dry seasons, but even where rainfall is relatively abundant throughout the year, biological seasonality is still a predominant feature.

Although evidence for seasonality in tropical faunas and floras is accumulating rapidly, relatively little is known about year-to-year variation in population sizes and reproductive activity. Collections of arboreal mosquitoes over a six year period, reported on by Galindo *et al.* (1956), demonstrated considerable year to year variation in individual species. Observations reported here further substantiate this finding.

METHODS

Two fluorescent black lights were positioned over screened windows in the laboratory clearing on Barro Colorado Island. The lights faced a ravine, covered with tall second growth vegetation near its top and with relatively mature forest farther down the slope. Thus the lights illuminated both canopy and understory vegetation. The vegetation remained essentially unchanged throughout the study.

Lights were turned on before dark and insects in several broad taxonomic groups were counted on the four window screens directly under the lights between 5 and 6 a.m. The numbers of individuals of several hundred species of moths, identified with photographic keys made during November 1967, were also recorded. Counts were made on 89 nights during the 10 months between November 1967 and August 1968, an average of almost 9 nights per month. The counts did not follow a regular schedule, and they varied between 4 and 12 per month in number.

A malaise trap with a cross-sectional area of 4 m^2 was also employed for 39 night periods and 29 day periods between November and June. The trap was located at ground level along a 5 m wide cleared path through second growth vegetation attaining about 5–10 m in height. The collecting bottle on the trap was usually emptied at dawn and dusk to separate day and night catches, but it was occasionally emptied every two hours during the day to obtain diurnal variation in flying insects. The wet weight of malaise trap collections was usually the only measurement of abundance recorded, but individuals of several orders were occasionally counted.

RESULTS

Major groups of insects. Monthly rainfall records for Barro Colorado Island, averaged for both 44 years and for the years during which this study occurred, are presented in Table 1. The climate is characterized by a rather severe dry season that usually begins abruptly in late December and ends somewhat more gradually in April. The timing and severity of the dry season vary considerably from year to year. Between 1926 and 1967, the rainfall during the period January through March varied by a factor of 27, between 0.6 and 16.3 in. (1.5 and 41.4 cm).

The seasonal occurrence of several conspicuous groups of insects attracted to the lights on Barro Colorado Island during the period November 1967 through August 1968 are presented in Table 2. Moths are divided into two size groups at a body length of 1 cm. Their seasonal occurrence will be discussed in detail below, although it is clear from Table 2 that the abundance of large species declined during the dry season months, and that the abundance of small species was least during the early part of the rainy season (April–June). Standard errors of the mean for the moth samples vary between 10 and 20% of the mean.

Patterns of abundance for other groups appeared to vary greatly. Katydids (Orthoptera: Tettigoniidae), beetles (Coleoptera), and both pentatomid and reduviid bugs (Hemiptera) occurred in fairly regular numbers throughout the year although katydids appeared to be more abundant during Feb–April, beetles exhibited a peak of abundance in May 1968, and reduviid bugs were relatively scarce in November 1967 and January 1968. Mantids (Orthoptera: Mantidae) were also scarce during November and December. Few bees, wasps,

Table 1. Seasonal distribution of rainfall on Barro Colorado Island.

RAINFALL (INCHES)	Month												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Average (1925–67)	2.2	1.3	1.2	3.5	10.8	11.0	11.5	12.4	10.3	13.6	18.1	10.5	106.4
1967	0.4	0.5	0.5	4.4	6.3	13.5	8.7	10.9	7.0	11.9	15.2	6.5	85.9
1968	0.1	1.8	3.6	0.6	11.5	10.2	6.5	15.9	7.1	18.7	10.2	1.8	88.1
1969	1.7	0.5	0.4	5.0	10.0	6.0	12.3	6.0	8.7	12.4	13.0	10.2	86.4
1970	11.8	2.8	1.3	4.2	18.0	8.5	13.3	14.1	5.2	10.9	20.0	16.8	127.0
1971	4.2	0.7	2.3	0.1	22.6	6.3	9.7	9.4	10.1	7.0	11.8	1.0	85.1

TABLE 2. Seasonal occurrence of certain groups of insects attracted to black lights on Barro Colorado Island, expressed as number of individuals per 10 nights of observation.

	MONTH									
	1967		1968							
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Number of nights	12	4	6	10	11	9	10	4	7	5
Taxonomic group										
Moths										
Large	314	512	168	217	157	310	348	258	446	394
Small	404	655	413	912	616	243	219	175	321	310
Katydids	20	12	8	44	36	33	17	23	23	22
Mantids	1	0	5	21	5	3	8	18	17	8
Beetles	3	15	5	13	12	22	61	15	21	20
Bees, ants, and wasps	44	78	17	17	17	58	251	38	50	12
Pentatomid bugs	4	10	5	3	3	10	2	5	1	10
Reduviid bugs	0	18	2	52	14	14	44	33	16	30
Cicadas	0	0	0	1	9	8	6	13	6	0
Owl-flies	1	0	0	0	0	9	9	0	3	2

and flying ants (Hymenoptera) were attracted to the lights during the dry season months (January–March) although tree flowering reaches a peak during this period. A marked peak in the abundance of Hymenoptera at the lights occurred during May 1968. Two smaller taxonomic groups, the cicadas (Homoptera: Cicadidae) and the owl-flies (Neuroptera: Ascalaphidae) were completely absent during large portions of the sample period and were most abundant during the early part of the rainy season.

Moths (Lepidoptera) were attracted to the lights in far greater numbers than any other group. Seasonal trends in their occurrence are shown in Figure 1. Large moths were least numerous during the dry months, January through March, and their numbers increased abruptly with the onset of the rainy period. As a whole, small moths exhibited no decline in numbers during the dry season. In fact, they appeared to attain peak abundance at that time. This peak consisted mostly of individuals of one species that was present at no other time, however; when this species was subtracted from the total, small moth abundance can be seen to decline through the dry season, reaching low levels between March and June (Figure 1).

The numbers of moths attracted to the lights varied greatly from night to night. Coefficients of variation, calculated for each month's counts and presented in Figure 2, demonstrated that the magnitude of short-term variation in small moths paralleled that in large moths and tended to decline slightly between November and August.

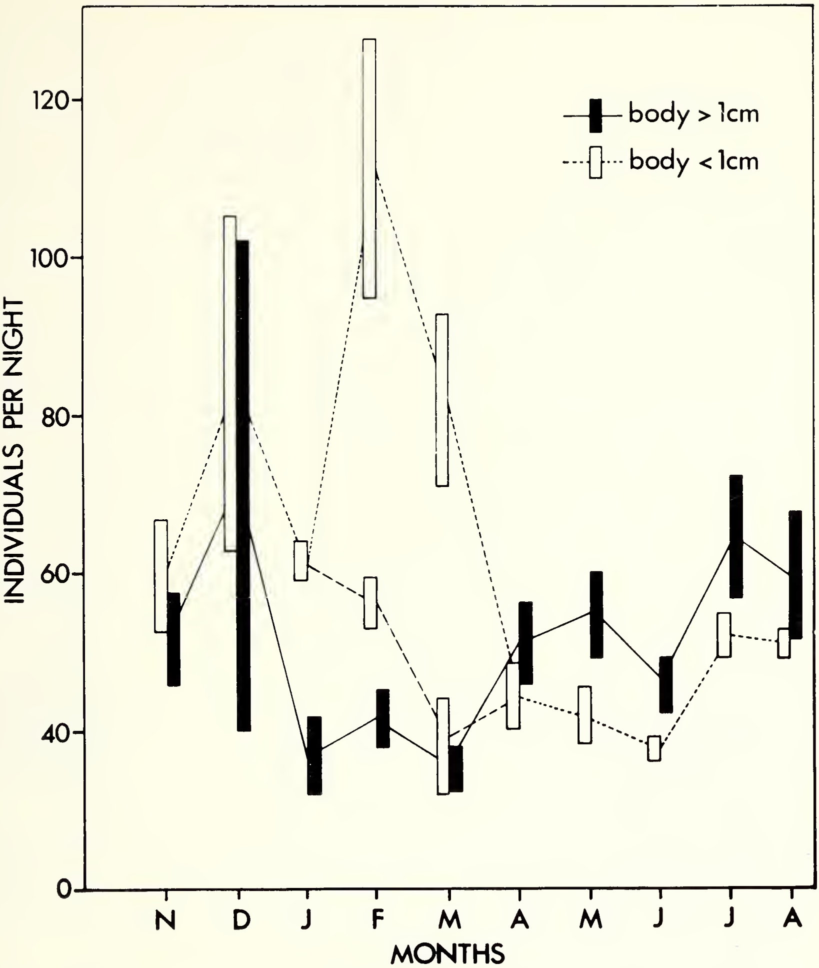

Fig. 1. Monthly averages of the number of individuals of moths attracted to the black lights on Barro Colorado Island between November 1967 and August 1968. Bars represent standard deviations. Solid bars and lines represent large species (body length greater than 1 cm); open bars and dashed lines represent small species. Two sets of figures are presented for small moths during February and March; one set includes, and the other does not include, a particularly abundant species present only during those months.

Daily records for the occurrence of moths at the lights indicate regular short-term cycles, particularly for large moths during the dry season (Figure 3). It is well known that the flight activity of moths varies more or less inversely with the brightness of the moon (Willliams 1936, Brown and Taylor, 1971). The periods of the abundance cycles do appear to be roughly four weeks, but peaks

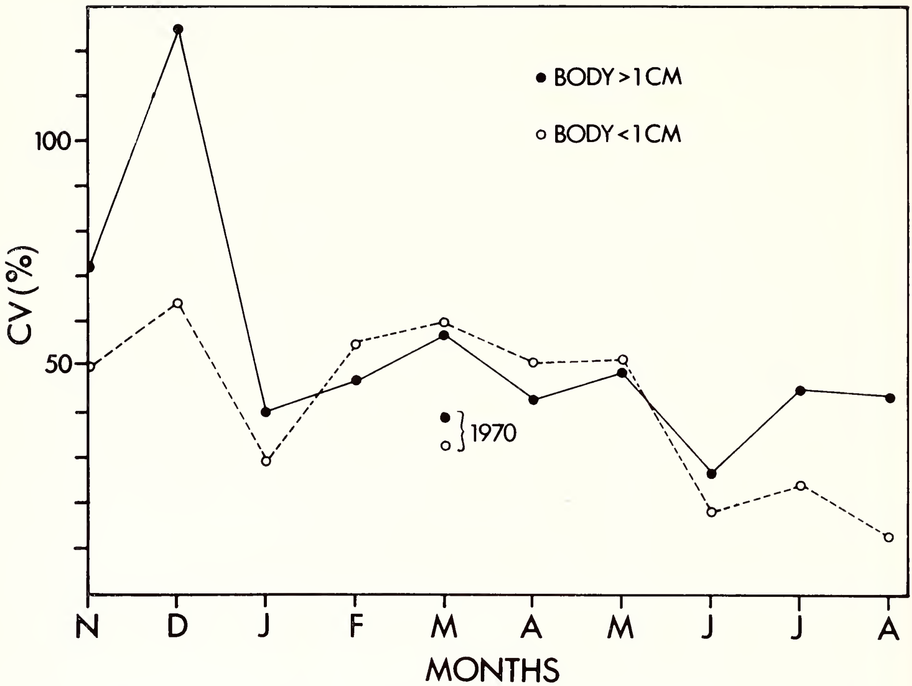

FIG. 2. Monthly coefficients of variation (standard deviation divided by the mean) of counts of moths attracted to black lights on Barrro Colorado Island, November 1967 to August 1968. Large and small species are distinguished. Data for 1970 are also indicated.

and troughs are not particularly well coordinated with new and full phases of the moon. Peaks timed according to this same periodicity seem to occur during November–December and April–June periods, but are out of phase and less well marked during July and August.

Individual species of moths. Records were kept of the numbers of individuals of several hundred species that were attracted to the lights each night. None of the species were identified. Most of these species were too uncommon to discern the presence or absence of marked seasonal trends, and many species were noted only once. The monthly averages for several of the more common species, shown in Figure 4, demonstrate a variety of seasonal patterns, ranging from relatively uniform distribution throughout the study period to the occurrence of marked peaks in abundance falling at different times of the year. All the species represented in Figure 4 appeared at least once during November, when a photographic numbered key to the moth species was made. Other species clearly showed narrow peaks of abundance during the dry season or early portion of the wet season. For example, in Figure 5, the nightly abundance of one very abundant

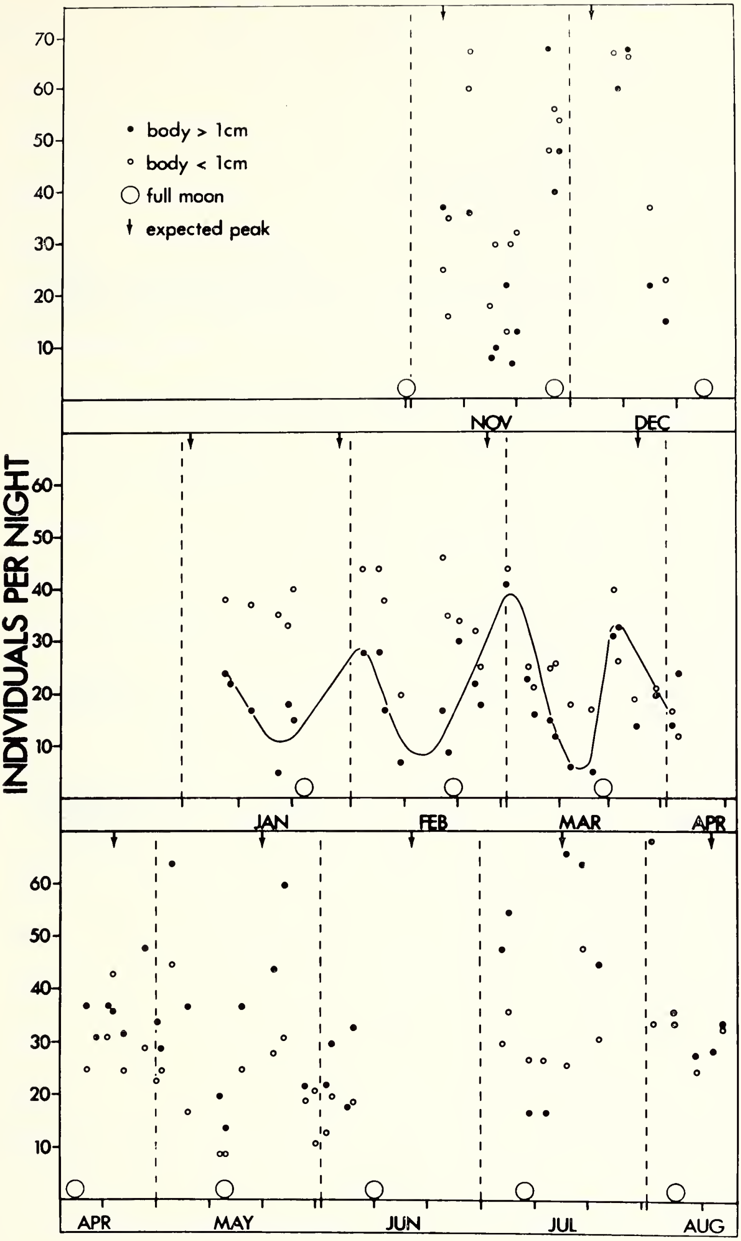

Fig. 3. Nightly occurrence of moths at the black lights on Barro Colorado Island, November 1967 through August 1968. Solid line in January through March suggests fluctuations in large bodied species. Arrows represent extrapolation of peaks of abundance at 4 week intervals throughout the sampling period.

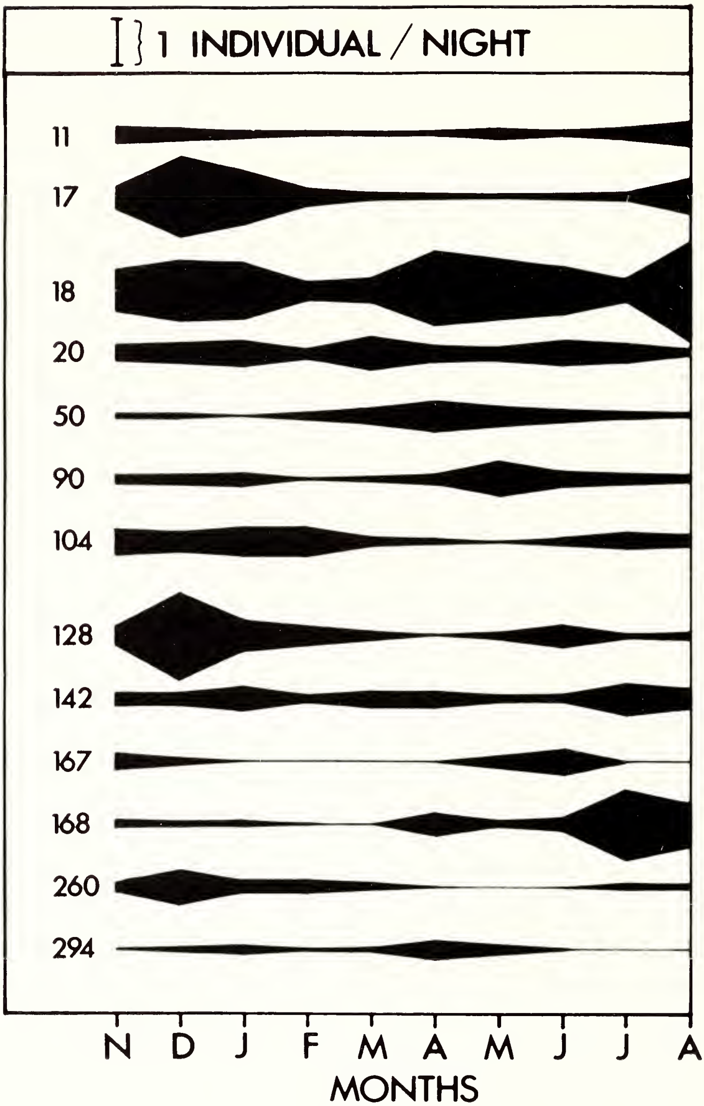

FIG. 4. Monthly average number of individuals of 13 selected species attracted to black lights on Barro Colorado Island, November 1967 to August 1968. Numbers refer to the photographic key used to distinguish the species.

small moth (unnumbered), present only during February and March, is compared to the more uniform seasonal distributions of the species of small moths numbered 17, 18, and 20. Fairchild (1942) also found great variety in the seasonal distributions of species of tabanid flies in Panama. By contrast, all the

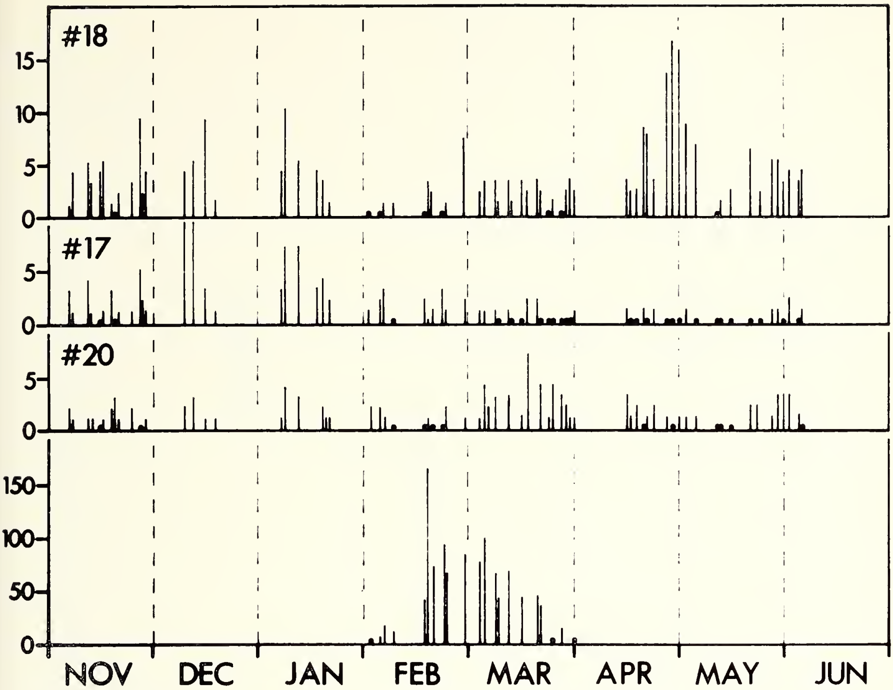

Fig. 5. Nightly occurrence of four species of small moths at the black lights on Barro Colorado Island, November 1967 to June 1968. Dots represent absence of a species on a particular night. Species numbers 17, 18 and 20 correspond to those species in Figure 4.

species of arboreal mosquitoes studied by Galindo *et al.* (1956) in the same region showed similar seasonal patterns of abundance, being almost completely absent during the dry season (January–April) and most abundant during the early part of the wet season (May–August). The seasonal pattern of abundance in these species is dictated by the fact that arboreal mosquitoes rely on the presence of standing water in tree holes and bromeliads for reproduction.

Malaise trap samples. Wet weights of insects caught during the night period were relatively high during November through January and about half as great during February through June (Figure 6). Daytime catches did not exhibit any marked seasonal pattern in total wet weight, however.

Most of the malaise trap sample collected during the night consisted of tiny diptera, which were not represented at the lights. So we should not be concerned over the lack of correspondence between the malaise trap samples and black light counts. Most of the daytime samples consisted of relatively large species of diptera and hymenoptera which reached peak abundance during midday (Tables 3 and 4).

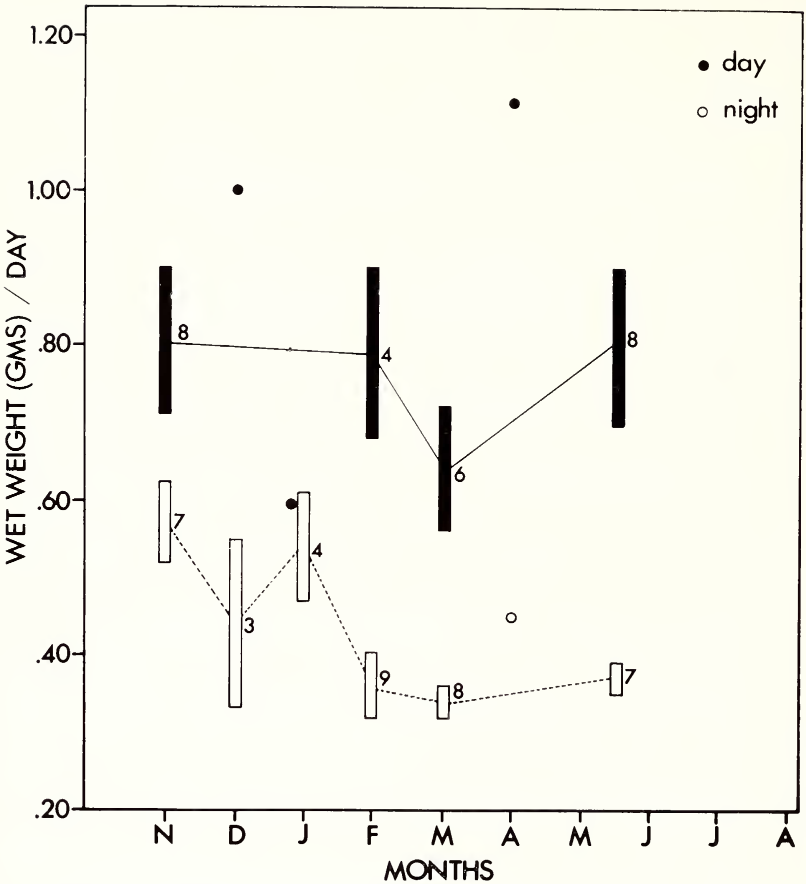

FIG. 6. Monthly averages of the wet weight of insects caught in a malaise trap on Barro Colorado Island. Daytime catches (0600–1800 hrs) and night-time catches (1800–0600 hrs) are distinguished. Solid and open circles represent single day or night samples. Bars represent standard deviations.

Year-to-year variation. Counts of insects attracted to the black lights during March 1970 and June and July 1971 are compared to samples counted during 1968 in Table 5. Differences between years are conspicuous for several groups. Comparing the month of March in 1968 and 1970, we note that large moths, mantids, beetles, and reduviid bugs were more abundant in 1970; no group was less abundant. The greatly increased number of beetles during 1970 was due to one species that had not been abundant at any time during the 1967–1968 sampling period.

Although the number of small lepidoptera counted during March 1970 was

Table 3. Diurnal variation in wet weight of malaise trap catch, November 1967 through May 1968.

Period	Samples	Hour of Day						Total
		6–8	8–10	10–12	12–14	14–16	16–18	
Nov. 6–Dec. 15	(7)	76 (13)	86 (19)	212 (32)	271 (38)	129 (15)	148 (20)	992 (92)
Jan. 19–Feb. 29	(3)	58 (5)	114 (34)	148 (18)	246 (61)	136 (33)	62 (38)	766 (160)
Apr. 30–May 27	(4)	28 (8)	167 (62)	250 (124)	356 (43)	110 (14)	73 (1)	1007 (123)

Note: All weights in milligrams; standard errors of the mean included in parentheses.

TABLE 4. Diurnal variation in the number of insects with body lengths exceeding 2 mm caught in the malaise trap.

Date	Group	Hour of Day						Total
		6–8	8–10	10–12	12–14	14–16	16–18	
Feb. 23	LEP	3	0	0	0	0	0	3
	DIP	1	3	12	6	5	1	28
	HYM	1	2	9	7	1	0	20
	COL	0	0	0	0	0	1	1
	TOTAL	5	5	21	13	6	2	52
Feb. 29	LEP	2	1	1	3	1	4	12
	DIP	1	6	13	11	7	9	47
	HYM	2	1	4	10	5	1	23
	COL	0	1	2	4	1	2	10
	TOTAL	5	9	20	28	14	16	92
Apr. 30	LEP	0	3	0	1	1	2	7
	DIP	3	6	13	16	10	7	55
	HYM	8	17	14	16	9	19	83
	COL	0	0	1	1	0	2	4
	TOTAL	11	26	28	34	20	30	149
May 22	LEP	0	0	1	2	0	2	5
	DIP	3	5	11	15	13	12	59
	HYM	0	3	2	8	3	2	18
	COL	0	2	1	1	3	2	9
	TOTAL	3	10	15	26	19	18	93
May 24	LEP	0	0	1	1	1	0	3
	DIP	4	6	14	17	5	5	51
	HYM	0	0	7	5	2	0	14
	COL	0	2	1	3	1	1	8
	TOTAL	4	8	23	26	9	6	76
May 27	LEP	0	0	1	0	1	1	3
	DIP	3	7	16	11	11	16	64
	HYM	0	0	6	1	3	2	12
	COL	0	2	0	2	0	2	6
	TOTAL	3	9	23	14	15	21	85
Entire Period	LEP	5	4	4	7	4	9	33
	DIP	15	33	79	76	51	50	304
	HYM	11	23	42	47	23	24	170
	COL	0	7	5	11	5	10	38
	TOTAL	31	67	130	141	83	93	545

similar to the number observed two years earlier, the particular species that comprised more than two-thirds of the total sample in 1968 (see Figure 5), accounted for less than one-third of the sample in 1970.

Differences in June and July samples between 1968 and 1971 were even more striking. Considering only June, moths were 3 to 4 times as abundant in 1971 as in 1968; numbers of katydids, hymenoptera were greater by factors of about 2, and numbers of cicadas and beetles, by factors of 8 and 15, respectively. Only

Table 5. Comparisons of insects attracted to black lights on Barro Colorado Island during different years.

	Month and Year					
	March		June		July	
	1968	1970	1968	1971	1968	1971
Number of nights	11	11	4	10	7	10
Moths						
large	157	421	258	822	446	761
small	616	654	175	730	321	654
Katydids	36	47	23	43	23	32
Mantids	5	17	18	8	17	23
Beetles	12	104	15	224	21	93
Bees, wasps and ants	17	4	38	91	50	57
Pentatomid bugs	3	4	5	20	1	7
Reduviid bugs	14	43	33	19	16	37
Cicadas	9	15	13	107	6	19
Owl-flies	0	0	0	–	0	–

Note: All figures are number of individuals per 10 nights.

reduviid bugs and mantids were less abundant. Differences between July 1968 and July 1971 were of a similar nature, but less marked in most groups.

It is tempting to relate the greater abundance of insects in the 1970 and 1971 samples, compared to 1968, to the unusually heavy rainfall during the months of January 1970 (11.8 in. compared to 2.2 in. average) and May 1971 (22.6 in. compared to 10.8). But since there are too few samples to treat the relationship between abundance and rainfall statistically, and since so little is known about the responses of populations to variation in rainfall in the tropics, it would be unwise to pursue this apparent correlation here.

In summary, the numbers of insects attracted to black lights at the edge of a lowland seasonally wet tropical forest exhibited marked fluctuation during the course of one 10 month period. Different insect groups had different peak and low periods of abundance, but the most conspicuous component of the samples, the moths, were least abundant during the dry season months. In samples taken at the same locality several years later, most groups exhibited strikingly greater abundances although the character of the vegetation had not changed. It is tempting to relate these increases to months of abnormally high rainfall just preceding the samples, but regardless of their cause, year-to-year variations in populations do occur in the tropics.

Literature Cited

Brown, E. S. and L. R. Taylor. 1971. Lunar cycles in the distribution and abundance of airborne insects in the equatorial highlands of East Africa. J. Anim. Ecol. **40**: 767–779.

Fairchild, G. B. 1942. The seasonal distribution of some Tabanidae (Dipt.) in Panama. Ann. Entomol. Soc. Amer. **35**: 85–91.

Galindo, P., H. Trapido, S. J. Carpenter, and F. S. Blanton. 1956. The abundance cycles of arboreal mosquitoes during six years at a sylvan yellow fever locality in Panama. Ann. Entomol. Soc. Amer. **49**: 543–547.

Janzen, D. H. 1967. Synchronization of sexual reproduction of trees within the dry season in Central America. Evol. **21**: 620–637.

Miller, A. H. 1963. Seasonal activity and ecology of the avifauna of an American equatorial cloud forest. Univ. Calif. Publ. Zool. **66**: 1–78.

Owen, D. F. 1969. Species diversity and seasonal abundance in tropical Sphingidae (Lepidoptera). Proc. R. Ent. Soc. London **44**: 162–168.

Pipkin, S. B. 1965. The influence of adult and larval food habits on population-size of neotropical ground-feeding Drosophila. Amer. Midl. Nat. **74**: 1–27.

Ricklefs, R. E. 1966. The temporal component of diversity among species of birds. Evolution **20**: 235–242.

Skutch, A. F. 1950. The nesting seasons of Central American birds in relation to climate and food supply. Ibis **92**: 185–222.

Smythe, N. 1970. Relationships between fruiting seasons and seed dispersal methods in a neotropical forest. Amer. Nat. **104**: 25–35.

Snow, D. W. and B. K. Snow. 1964. Breeding seasons and annual cycles of Trinidad landbirds. Zoologica **49**: 1–39.

Williams, C. B. 1936. The influence of moonlight on the activity of certain nocturnal insects, particularly of the family Noctuidae, as indicated by a light trap. Phil. Trans. Roy. Soc. London (B) **226**: 357–389.

Wilson, D. E. 1971. Ecology of *Myotis nigricans* (Mammalia: Chiroptera) on Barro Colorado Island, Panama Canal Zone. J. Zool. Lond. **163**: 1–13.